XIII.—*On the Functions of the Nitrogenous Matter of Plants.* By M. L. Garreau.

[Concluded from p. 43.]

II. *Of the Circulation.*

The intracellular circulation observed by Corti, and since studied by Treviranus, Amici, Robert Brown, Schultz, Raspail, Meyen, Slack, Pouchet, Dutrochet, Schleiden, Steinheil, Becquerel, Dujardin, Schacht, Trécul, Hugo Mohl, &c., in a small number of plants, has been hitherto generally regarded as a simple motion of rotation, and as peculiar to certain plants. But, from the constant presence of living nitrogenous material in cells in course of growth, the modifications in form that it undergoes, and the vital movements with which it is endowed, and which we shall presently point out in detail, I hope to show that we have not always to deal with a simple act of rotation, and that this movement is as general as the cell. All plants, and their parts, in which the nucleus and its appendages are readily discoverable, are suitable for the study of the vermicular movements of the intracellular circulation; and it is sufficient to select for examination a hair or a thin slice of tissue, in the conditions before indicated, to demonstrate this beautiful phenomenon. One plant in which it displays itself under the greatest variety of form is the *Salvia sclarea*. This vigorous labiate plant has its surface everywhere covered over, and particularly its young merithalli, with large hairs, beautifully transparent, and formed by two or three superimposed cells, the septa between them being also perfectly translucent. If a small slice of the hairy epidermis of this plant be examined under water, the canals through which the circulation is carried on are perceived at once in the hairs fringing the section; and on following attentively their course from the periphery, or from any other point, towards the central nucleus, the granules which stream through them may be noticed making their way to the nucleus, whilst some of them are driven against the lateral and opposite portions of the canals in which they circulate. The rapidity of these currents is augmented by heat, and varies in each canal: it is almost inappreciable at 10° Cent., but considerable at 25° to 30°; the granules in one stream sometimes traverse the half of the long diameter of a canal in a few seconds, whilst those in others occupy some minutes in accomplishing the same distance. Again, in some canals the circulation becomes arrested for a moment, and sometimes this stoppage is instantaneous. All these centripetal currents are equally distinguishable both through the anastomosing canals and through those that do not anastomose; and, during their continuance, these canals are some of them stretched like rigid threads across the cell-cavity, whilst others are slack and more bulky.

On my first observation of these currents, I speculated on the causes of the movements; but I might have probably ended with the simple recognition of the fact of their existence, had not the cause itself been unfolded to my observation, viz., the power of contraction. On seeing this strange phenomenon, which I looked upon for a long time with that restless curiosity which astonishing and entirely unexpected circumstances produce in the mind, I was disposed to attribute it to some illusion; but at length I was *perforce* obliged to yield to evidence obtained by observations repeated 500 times during a period of ten years, upon the *Salvia* named and on very many other plants, and all of which have led to the same results. The contractions of the canals usually proceed progressively, in such a manner that the granular fluid is propelled gradually onwards—a dilatation larger or smaller appearing in advance of the contracted portion, and preceding it, until the granules reach the nucleus, where their course is arrested until they coalesce with it. In their progress towards the nucleus, these dilatations are frequently retarded in their course by the spots where anastomosing canals meet; and they do not reach the nucleus until after they have proceeded upwards, downwards, or laterally, according to the disposition of the anastomosing parts. Whilst these contractions continue, the canal, contracted behind and much dilated in front, seems to outstretch itself, and to be thrown into undulations or folds, which are most numerous near the nucleus. It might be supposed at first that, as is seen in most of the membranous processes of the hairs of the pumpkin or gourd, and in those of still very young cells, the membraniform, soft, very extensible material is a viscid matter which has an inherent motion towards the nucleus; but if we observe a canal having a direction parallel to the axis of the cell, and bearing an anastomotic branch perpendicular to it, the latter is gradually pushed towards the nucleus, forming a more and more acute angle; and when the contraction is past, as relaxation slowly succeeds, it is seen to resume more or less closely its original relations, and form anew a right angle to the canal it communicates with.

Nevertheless, in citing this example, it is not my intention to assert that the canals have a permanent fixed position; for this is not in accordance with fact, since we know that the organic matter they are composed of is susceptible of movement and of displacement. The distinguished observer Meyen seems to have obtained the first perception of a portion of the movements which take place in the living matter of cells; but his conclusions testify to his having made observations under unfavourable conditions; for he assumed them all to result from the currents of the intracellular mucilaginous matter which successively coalesced and separated from each other. But there is no question that this naturalist would have given a better description of them if he had persevered in the examination of what he saw, varying the subject and the conditions of observation; for he then might have convinced himself that most of these currents take place in actually contractile canals, through which the numerous granules circulate with a greater rapidity than the centripetal movements of the soft matter which constitutes them—a fact which could not take place if they were transported with this matter; moreover, he would have likewise witnessed the minute granules circulate in tense and completely motionless canals, the contents of which received their impulse from contractions remote from the communicating canals. Hugo Mohl has certainly seen some of the facts that I have remarked; for he recognized the existence of minute canals in the intracellular animal matter which he calls the protoplasm; and Slack, whilst denying the existence of canals in certain cells, remarks on the subject of the circulation in the cells of *Hydrocharis morsus-ranæ*, "The small globules follow the larger; and occasionally one of the green globules crosses the cell in a current of still more minute particles, forcibly traversing a canal which can scarcely admit them." The canals which are formed in the animal azotized material of a cell do not always contract themselves gradually; it is not uncommon to see several of them at a time, by a *brusque* movement, drive forward the granular fluid that they contain. Under such circumstances these canals insensibly enlarge; and whilst the fluid that is to be propelled by their contraction flows through them, they may often be seen to change their relative position, and to undulate like imperfectly stretched cords until they acquire an increased rigidity and an enlarged capacity; then they become outstretched, assume a dull-white hue, and contract once or oftener in succession. After these contractions have occurred, the partially emptied canals, more elongated than formerly, occasionally reunite in a bundle, fixed on one hand to the extremity of the cell, and on the other hand to the nucleus—a bundle which then simulates a mucilaginous-like axis without distinction of parts. However, if the observation be pursued, after half-an-hour or sometimes more, according to conditions which I have found it impossible to appreciate distinctly, these same canals fill themselves afresh and resume their contractility. Such is the mechanism by the aid of which the granular fluid contained within the living azotized material flows from the periphery towards the nucleus.

There likewise exists a centrifugal movement, which goes on by a series of slower contractions, also less marked, and of variable rapidity in different canals. The nucleus itself contracts; but its contractions are slow and gradual, and its movements are only appreciable through its changes in relative position and volume; for when these contractions take place, it is seen to diminish almost insensibly in magnitude, and to assume a dull-white tint, undergoing at the same moment an inconsiderable amount of displacement. At the least, this organ, suspended like the canals and the viscous currents in the cell-cavity, suffers displacements to a much less limited extent than is generally imagined: this depends on causes inherent in the contractile and extensile properties of the nucleus and its appendages. I have not as yet succeeded in determining whether the granular fluid can return from the centre to the periphery through the whole of the canals that it has traversed to reach the nucleus; but we may convince ourselves that, among the parallel canals through which the circulation proceeds, it is in some of them centripetal, in others centrifugal. But as the canals are all in connexion with the nucleus, we must assume that this organ is capable of effecting partial contractions, as the canals themselves can do; for otherwise, if its whole mass were acted upon at the same moment, it would not be conceivable how centripetal and centrifugal currents should proceed simultaneously.

The fluid in circulation is ordinarily limpid; however, in plants having a white latex, such as *Campanula pyramidalis, Sonchus oleraceus*, &c., it has a certain degree of opacity; and in *Chelidonium majus*, yellowish granules are interspersed within it. Consequently it may at least be supposed, if it be not admissible as a legitimate conclusion, that the matters contained in the laticiferous vessels derive their source from the granules of the nutrient fluid within the cell-cavity. The granules carried forward in the currents are of two sorts: one, tolerably numerous and nearly spherical, congregates in the nucleus in much greater abundance than in the canals; the other occurs in molecules of extreme tenuity and less regular in outline, which seem to be slightly more dense than the fluid in which they float; for in *Tradescantia virginica* and *Erodium moschatum*, plants in which they are readily discernible, they are more aggregated at the lower part of the canals than at their centre.

The nutritive fluid not only moves through the canals which float freely within the cell-cavity, but also in those which constitute a network in the primordial membrane, and in those of less size which are obliquely distributed on its internal surface.

To detect this portion of the circulation, considerable patience and care are required. The canals in which it goes forward are, by artificial light, more transparent than the membrane they permeate; and in tracing their course little dilatations may be observed to slowly form and presently vanish; in these we have the counterparts, on a minuter scale, of those dilatations seen to arise during the contractions of the free canals stretched across the cell-cavity.

Lastly, to sum up this list of facts, if a still fresh hair be selected, having however the primordial membrane of its cell detached to a very limited extent from its cellulose wall, the same movements are discernible in the unbroken filaments connecting those two laminæ of the cell; only, owing to the extreme tenuity of these filaments, the saccular dilatations are very minute, though always visible by a magnifying power of 300 or 400 diameters. The whole of the movements going forward within the intracellular nitrogenous material are arrested when the cells are immersed for a few minutes in an aqueous solution of sulphate of strychnine, containing one part of the salt in 200 parts of water. The acetate of morphine, of the same degree of dilution, produces similar effects, though not in less than double the time taken by the strychnine. The transparent hairs of *Erodium moschatum*, from the young merithalli, are well suited for making these observations on. The same may be said of the hairs of *Chelidonium majus*, *Glaucium glaucum*, of the cellular tissue of the epidermis of *Sedum*, and of that of the petiole of *Dipsacus fullonum* and of *Arum*, &c., except that in the last-named examples it is less easy to study the phenomenon, because their vital movements are more obscure, and their cellular walls less transparent.

The movements that take place in the nitrogenous matter of cells are not limited in their effects to the circulation of the granules contained in the canals and nucleus, but produce also an incessant fluctuation in the aqueous fluid which surrounds them and fills the cells, and so cause a movement of rotation of the same character (though less marked, it is true) as that observed in the cells of *Chara*, *Nitella*, *Hydrocharis morsus-ranæ*, of *Stratiotes aloides*, &c. Still it is very visible, the liquid having numerous small molecules suspended in it, if attentively observed; and its course may be detected in the hairs of Labiatæ, &c. Thus there are two sets of distinct movements within the interior of cells,—one spontaneous, due to the contractility of the living material itself; the other passive, dependent on displacement of the surrounding liquid.

In the exposition just made of the mode of existence of the living matter of cells, of its proper movements, and of those it impresses on the fluid surrounding it, our investigations have been restricted to only that portion of it which enters into the formation of the nucleus and of the canals and contractile filaments; however, in many plants, and among others in the epidermic cells of young Arums, in the hairs of Umbelliferæ and of Boraginaceæ, in the epidermic cells of the leaves of *Scolopendrium officinarum* vel *undulatum*, the azotized or living material loses the characters detailed, and is represented only by filaments which emerge from a semifluid mass and stretch themselves towards the primordial membrane, exhibiting changes of position very slowly, and impressing some movement on the fluid bathing them. It is a fact that most physiologists who have interested themselves in the rotary movement which occurs in the cells of *Chara* attribute it to other causes; but in our opinion there is only one true explanation of it, as pointed out by Schleiden, Hassall, and Hugo Mohl, who have rightly perceived its mechanism, and attributed it to the dense fluid which occupies the inner wall of the cell-cavity. Dutrochet and Donné have inspected its cause in the nearly mature merithalli of plants,—the first-named in the course of attempts to suspend its course by means of poisonous agents, and the second in recognizing the spontaneous movements of detached and vermiform fragments of the primordial membrane. Nevertheless these naturalists seem to assign an influence to the green globules which they do not possess; for these chlorophyl-granules are scarcely apparent in the very young ramifications of *Nitella flexilis*, and are entirely absent in the cortical cells of the rhizomes of *Chara*. Nevertheless the circulation is very much more active in those parts than in merithalli of greater maturity, wherein the green globules more abound. They, in fact, contain a nitrogenous plastic material, filled with excessively minute molecules, which creeps along the wall of the tube, and impresses upon the aqueous liquid in contact with it, and loaded with globules, a similar movement. What proves that such is the cause of the motion in young cells is, that though this nitrogenous matter be more dense than the fluid with which it is bathed, it raises itself and moves along the tube contrary to the action of gravity, and advances with incomparably greater velocity than that of the fluid which accompanies it in its course. In proportion as the merithalli are developed, this matter gets fixed to the primordial membrane, in the formation of which, indeed, it takes part, and which, though adherent to the cell-wall, propels onward the enclosed liquid of the cell, not, as has been suspected, by the aid of vibratile cilia, but by tolerably rapid undulations similar to those produced on the surface of water ruffled by a gentle breeze.

If, instead of limiting the examination of the vital movements of the nitrogenous matter in the interior of the cells of phanerogamous plants and of some Characeæ, we extend it to Cryptogamia generally, both vascular and cellular, it will be found that this vital act, whilst the subject of various metamorphoses, presents itself in individual organisms of determinate form, which have for a long time been confounded with Infusoria.

The antherozoids of *Chara, Nitella,* of Ferns, Mosses, Equisetacæ, Hepaticeæ, &c., have been well studied, and described in relation to their development, forms, and vital endowments, by Thuret, Nägeli, Suminski, Pringsheim, Derbès and Solier, and others. Let us examine and discover whether the spontaneity of movement with which these organisms are endowed be open to question, and whether their origin in the metamorphosis or development of the living proteine matters of the cells be still a debatable point. For ourselves, we have examined them in several *Charæ,* in *Nitella flexilis,* in *Marchantia polymorpha,* &c.; and both the contractility and spontaneity of their movement have appeared so decided that we have no hesitation in saying, with all deference to those naturalists who deny them these properties, that their observations must have been made at inopportune seasons.

The zoospores of *Vaucheria clavata,* mistaken by Nees von Esenbeck for Infusoria, have been examined with respect to their origin by Meyen, whilst Unger and Thuret have presented an accurate history of their organization. Likewise the sporozoids of different Fucaceæ have been studied by Decaisne and Thuret, particularly by the latter observer, who has investigated with the greatest care both their organization and their vital endowments, in a large number of species. Now, on contemplating these locomotive organisms we shall perceive that, if the living nitrogenous materials seen in movement within the cells of phanerogamous plants have not the determinate form of Infusoria, like that of the animalcular beings of antheridia and zoospores, there exists nevertheless between the two the signs of a common parentage. And it is a striking circumstance that the actually living and moving zoospores proceed, so soon as fixed by one end, to change their shape and to develope cells; but although dead so far as concerns our view, by reason of the screen which conceals them from our research, still their substance carries on a latent mode of life, and elaborates a plant which in course of time resuscitates the motile organisms. Is not this circle of life sufficiently remarkable to attract the highest attention of micrographers and physiologists? for does it not seem to reveal to us the true nature of plants? It is true that the differences between the Algæ and the immense majority of other plants are very wide; still we must not seek after the affinities between them in accessory functions, but in the movements and principal functions of their nitrogenous matters.

These movements are visible in all plants in process of growth, but exert no marked action upon their cell-walls, because these last are too resistant. However, in *Oscillariæ* (some of which are elongated in the form of worms, whilst others are coiled in spirals) we meet with novel conditions of existence, by the operation of which the living matter of those plants, without any perceptible change of nature, subsists without the presence of that cuticle or epiderm which limits their motions. Suppose, for example, an *Oscillaria* to be enveloped in a more resistant cellulose coat, and we shall realize to our minds the presence of all the organic elements of a ligneous fibre. Or suppose, again, a similar covering imposed upon *Amœba diffluens*, and we shall recognize in it all the elements of a parenchymatous cell. Granting that the nitrogenous matters within the cells of plants possess the property of motion and of reproduction like animals, do they, let us next inquire, partake those other functions which belong to the latter?

The proteine matter of plants, which serves for the development of that of animals, has hitherto not been completely separated from the organic and inorganic elements with which it is associated; but we have elsewhere shown that it tends to isolate itself in seeds containing earthy and alkaline phosphates.

On analyzing the gluten obtained from cereals we discover the same animal and mineral substances, very little modified, as are found in our own tissues. If this same gluten be brought into contact with a globule of yeast, it becomes entirely transformed into a mass of globules resembling those of the fungus, which is itself composed, with the exception of its scarcely visible enveloping lamina of cellulose, of the elements of gluten, and in the same proportions.

On cautiously removing the endochrome of the merithalli of *Chara*, the same chemical compounds, besides the fatty matters and the traces of starch, are discoverable. And, indeed, the fact seems well established that there is no difference between the composition of the living matter of plants and that of animals.

It is, notwithstanding, true that the proteine matters of plants are constantly impregnated with cellulose, whilst those of animals are only exceptionally so, as in the example of Tunicata and *Diselmis*.

In the views we propound regarding the vital movements and the chemical composition of the proteine material of plants, it is not our intention to maintain that animals and plants are organized in the same manner, and have the same sensibility; the only principle we advance is that the living matter of plants and animals has a similar chemical constitution, and that this material in plants performs essential functions similar or analogous to those of animals.

It has for a long time been the general belief that plants, reversing the rule prevailing in animals, respire carbonic-acid gas, which they extract from the soil or withdraw from the atmosphere, and that whilst they assimilate its carbon they throw off its oxygen—or that, in other words, a plant seems to respire by the medium of an asphyxiating agent. However, when we consider that the Fungi, the majority of Algæ, the Orobancheæ, the roots, stems, flowers, the green fruits, &c. of all phanerogamic plants constantly give off carbonic acid as a result of a process of combustion between their carbon and the surrounding oxygen, we must feel obliged to admit that plants respire like animals, and that the final result of the respiratory act consists, equally in the two, in the decarbonization of their fluids or of their tissues, and in the production of heat.

M. Bérard, in a prize thesis of the Academy of Sciences, has shown that green fruits, even the youngest, exspire, whether in sunshine or in the shade, notable quantities of carbonic acid. I have moreover proved, in a series of memoirs published in the 'Annales des Sciences Naturelles,' by means of numerous experiments, that buds and the young shoots succeeding them, adult leaves, &c. consume a portion of their carbon by the aid of the surrounding oxygen, or of that which they form within their tissues; and that this function, which diminishes in activity as the leaves grow old, is more marked when it proceeds under the influence of a higher temperature. These facts, confirmed as they are by the most recent researches, establish clearly enough that plants are endowed with a respiratory function like that of animals, extending over the day as well as the night. At the same time it must be granted that their diurnal animal respiration is rendered more or less obscure in its results, as it can be accomplished by the aid of the oxygen derived from the decomposition of the carbonic acid it produces, and which it incessantly gives off within the laminæ of their tissue or in the atmosphere. It is very easy to demonstrate this double interchange by placing a green plant or the leaves of one in a limited amount of atmospheric air, and in the presence of some solution of baryta, when the latter will be soon covered with a pellicle of the carbonate of that earth; whereas if the experiment be performed under the same conditions, omitting the baryta, no trace of the carbonic-acid gas will be discoverable.

It is equally easy to establish the relation that subsists between this act of animal respiration and the development of caloric from it as a natural result. We may here recall some experiments made by De Saussure, Dutrochet, and Adolphe Brogniart, as supplementary to those which we can ourselves adduce in support of the same truth.

Dutrochet has demonstrated ('Annales des Sciences Naturelles,' 1845, p. 5) that all parts of plants possess a degree of heat superior to that of their surrounding medium, and that the elevation of temperature noticed in the *Arum*, the *Caladium*, &c., is only a more marked manifestation of a phenomenon common to all living beings. But this phenomenon itself is nothing more than a feeble reflex of a more material fact, viz., that of the chemico-vital combustion of carbon by oxygen. Thus, in the instance of plants as of animals, the respiratory act has for its final appreciable result to carry off carbon and to raise their temperature; and these two effects are intimately correlated in both sets of organisms; for the researches of De Saussure show that tubers, roots, ligneous stems, &c., give off only one-half of their volume of carbonic acid in the twenty-four hours; whilst those of Dutrochet have demonstrated that the heat belonging to those parts is scarcely appreciable.

The former of these observers has remarked that in monœcious flowers the males consume more oxygen than the females; and the latter has noticed that their temperature is also more elevated. The researches of Sennebier on the heat of *Arum maculatum*, those of Schultz on *Caladium pinnatifidum*, those of Goeppert on *Arum dracunculus*, of Brongniart, Vrolicke, and Vriese on *Colocasia odora*, as well as those long ago made by Lamarck, and our own on the spadix of *Arum italicum*, establish most distinctly the cause of the phenomenon and its relations with the oxygen and the carbon consumed. The following Table of the heat of certain plants, and of the quantity of carbonic acid expired by them during a certain time, represents the approximative results arrived at by Dutrochet and other observers:—

Name of plants.	Oxygen consumed in 24 hours.	Observer.	Medium heat.	Observer.
Green Pear	0·50	Bérard.	0·06	Dutrochet.
Green Pear	0·70	Id.	0·06	Id.
Plum (*Reine Claude*)	1·60	Id.	0·09	Id.
10 grs. of leaves of House-leek	0·20	Garreau.	0·03	Id.
Spathe of *Arum maculatum*	4·00	De Saussure.	0·22	Id.
Spadix of do.	38·00	Id.	4·60	Id.
Stamens of do.	135·00	Id.	7·00	Id.
Pistils of do.	10·00	Id.	1·50	Id.
Flower of the Gourd	7·60	Id.	0·50	De Saussure.
Boletus aureus	7·50	Id.	0·45	Dutrochet.

From these facts, derived from different sources, it is at once evident that a well-marked relation subsists between the quantity of carbon consumed and the elevation of temperature produced. These results, it is true, are deficient in that degree of precision that researches of this nature should possess; for it is to be regretted that De Saussure and Bérard have neglected to indicate exactly, as Dutrochet has done, the mean temperature at which the observations have been conducted. Notwithstanding this omission, however, the relations pointed out are real.

The following Table, conveying the results of our own observations, moreover shows the relations subsisting between the oxygen consumed and the degree of heat emanating from its union with the carbon in the plant:—

Respiration of the spadix of *Arum italicum,* at the temperature of 20° Cent., and during the period of its sexual activity.

	Heat of spadix.	Medium heat hourly.	Oxygen consumed.	Volume of oxygen consumed; the organ being taken as the unit.
h. m.			cub. cen.	
1st hour { 3 30 / 4 30	2·5 / 3·9	3·2	39	11·1
2nd hour { 4 30 / 5 30	3·9 / 7·6	5·3	57	16·2
3rd hour { 5 30 / 6 30	7·6 / 8·9	7·8	73	21·4
4th hour { 6 30 / 7 30	8·9 / 7·7	8·3	100	28·5
5th hour { 7 30 / 8 30	7·7 / 4·2	6·0	50	14·2
6th hour { 8 30 / 9 30	4·2 / 1·2	2·7	20	5·7
Mean		5·3	56·8	
Oxygen consumed in the 6 hours		...	339	

It may be objected that the production of carbonic acid within the vegetable tissue, and that of the caloric which results from it, are the consequences of a purely chemical action, and not of a physiological process. But if we consider that the researches of Théodore de Saussure, of Bérard, and of Dutrochet have been made on living organs in process of growth, that parts of plants when broken or bruised up cease to form carbonic acid, as the experiments of De Saussure, Frémy, and ourselves demonstrate, and, lastly, that the death of the tissue, as evidenced by the persistent loss of movement of the nitrogenous living material, involves the cessation of the development of this gas, the conclusion is inevitable that its formation is the consequence of a vital act. What, in conclusion, along with the causes just enumerated, convinces us that the animal respiration of plants has its seat in the living nitrogenous matter which is seen in circulation within the cells is the relation which exists between the quantity of this matter contained in a living organ and that of the carbonic-acid gas exhaled.

The subjoined Table, taken from our first memoir on the respiration of plants ('Annales des Sciences Naturelles,' 1851, p. 5) appears to bear out this assertion:—

Matters examined.	Temperature.	Acid exspired in 24 hours.	Observations.
White pith of Elder	17°	0·0	The yeast was spread on unsized paper, and suspended in the air of the apparatus.
Wood of oak, in fine chips	17	0·0	
Carrot	17	0·8	
Fresh alburnum of Elder	17	4·5	
Do. do. of Horse-chestnut	18	5·0	
Root-fibres of Groundsel	17	5·5	
do. of Mercurialis	17	7·0	
Boletus aureus	18	7·5	
Yeast, of the consistence of paste	15	14·0	
Yeast, washed with distilled water	18	20·0	

According to these experiments (in which the volume of the organ respiring is taken, for comparison sake, as the unit), those portions of plants deprived of living azotized matter carry on no respiratory act, whilst those which, like very slender fibrils, alburnum, fungi, yeast, &c., are richly furnished with it, fulfil that function the more actively in direct proportion with the quantity secreted or deposited. It is worth remarking that seeds and fruits, although rich in proteine matters, produce only a minimum quantity of carbonic acid; but this at the same time is explicable on account of those substances being coated by dense envelopes, rendering them scarcely permeable by the oxygen, and of their relative volume as compared with their very small surface. These obstacles to their respiratory activity are, however, indispensable to their normal development; for otherwise neither starch, nor oil (so necessary to the germination of the young embryo), nor pectine, nor sugar, nor the ligneous deposits of fruits could be produced, if the carbon, the essential element in their formation, were consumed. A proof that this assertion is true is furnished by the analyses of M. Boussingault, which prove that fruits and seeds so placed as to facilitate the action of oxygen, and thereby to stimulate and promote the vital movements of the nitrogenous matter, carry on a respiratory function and are deprived of a great part of their carbon without any loss of their nitrogen.

The proteine material of plants exerts on the respiratory pabulum laid up a similar action to that which animal substance exercises on the same matter, and in such a manner that the more an organ is permeable to the air, and rich in nitrogenous material, the less will be the quantity of starchy, oleaginous, and saccharine products it accumulates. This circumstance may be illustrated in the case of fibrils, young leaves, petals, stamens, and the herbaceous stems of vegetables when forced to exuberant growth by manures. The contrary obtains in proportion as the contact with oxygen is lessened, as may be seen in fruits, seeds, and bulky roots, all which are structures in which we find those starchy and cognate alimentary matters in greater or smaller quantity, or artificially accumulated in still larger proportions by preserving some portions of the plants from contact with the air (e. g. potato and beetroot).

The action exercised by the proteine matter on the pabulum for respiration, though at first having a contrary purpose, has nevertheless, when of a certain intensity, the tendency to shorten the duration of the organ in which it proceeds, or at least to diminish its consistence. For example, young fibrils, petals, stamens, fungi, &c., rapidly wither; and the stems of flax and of our cereals, when their growth is too much forced by highly nitrogenous or too abundant manure, become overturned and laid on the ground from the insufficiency of those cellulose and encrusting deposits to which under ordinary conditions they are indebted for the powers of resistence to the influence of the rain and wind.

The conclusions deducible from the facts set forward in this memoir are, that the living azotized matter seen in motion within the cells of plants unites in itself the principal attributes of that which enters into the nature of animal life: it possesses the like excitability, contractility, and elementary composition; its respiration, in all that concerns its more appreciable results, differs in no way from that of animals. But whilst the proteine matter of plants possesses in itself the composition and some of the principal functions of that found in the superior animals, it likewise possesses an assimilating force not met with except among the lowest animals, whereby it brings inorganic matters into connexion with its own proper substance and with that of animals.

[*Observations.*—The foregoing essay evinces much diligent micro-chemical research, and furnishes a valuable contribution to our knowledge of the internal economy of plant-cells. But, whilst acknowledging thus much, we are not disposed to accept the writer's interpretation of much that he describes. The marvellous internal arrangement of vessels, carrying on a circulation of fluid, radiating from the nucleus and forming a network in the primordial tunic communicating with a similar vascular apparatus in surrounding cells, appears to us a creation of the imagination misled by microscopical appearances—a resurrection of hypotheses of complicated organization in the economy of the simplest organisms, such as modern research has demolished in the case of the Infusoria. In many respects, indeed, the descriptions of M. Garreau might pass for a *réchauffé* of Schultze's romantic hypothesis of an all-wide-pervading system of laticiferous vessels throughout vegetable tissue.

Yet, though dissenting from M. Garreau's interpretation of appearances he met with, we readily admit his general accuracy as an observer. We receive his account of cord-like processes extending from the nucleus to the primordial utricle of the cell, of their variability in dimensions and in their degree of tension, and of the centrifugal and less active centripetal currents of granules passing through them; but we discover in all this no evidence of vessels ministering to a circulation properly so-called. On the other hand, we find a precise analogy to it in the internal organization of the animals of the class Rhizopoda—the Amœbeæ, Foraminifera, &c. In the thin filiform processes of the Foraminifera we observe a streaming outwards of granules from the central mass of sarcode, followed by a backward current towards it, and at the same time a variability in the volume, tension, and direction of those processes. In these phenomena, however, naturalists do not recognize the existence of a vascular system, but see in them only the illustration of vital action, or the results of the nutritive force, operating as an attracting agent and establishing currents in the nutrient juices of the organism.

We would apply these views in the interpretation of the structural arrangements seen by M. Garreau. The nucleus doubtless represents the germinating and actively nutrient centre of the cell—the formative material,—whilst the surrounding cell-wall is the completed or formed matter, added to and advanced in growth so long as the nucleus retains its formative energy and power of assimilating new material from the inorganic matters reaching it through the osmotic action of the cell-wall. As such an active agent in nutrition, the nucleus operates as a central force, whilst the process of growth of the cell-wall, or chiefly of the primordial utricle, establishes nutritive currents which will be directed towards it. Space compels us to curtail our remarks on this physiological subject, which has been well worked out by Dr. Beale in his recently published lectures, originally delivered before the College of Physicians of London.

We will, however, venture an observation on the enveloping wall of the nucleus, which M. Garreau appears to have demonstrated, by asking, How far do those apparent membranes owe their origin to the mutual reaction of the simple organic material and the surrounding fluid? Chemistry demonstrates how very materially substances are affected by the chemical taking up of water; and there is good evidence to show that organized tissue may be very greatly modified in its chemico-vital endowments by contact with water and other fluids, and that the formation of a pellicle or film around it is no proof of the histogenetic independence of this film as a tunic. These inquiries are further suggested by Auerbach's researches, according to which a membrane encloses and limits the whole simple substance or sarcode of the Amœbeæ, although all the phenomena of variability, of adhesion, and of confluence of their processes proclaim the contrary. In reference to these researches we will finally ask, Do not the very means resorted to in order to detect the existence of a limiting membrane concur to produce a pellicle which may be mistaken for the independent structure sought for?—J. T. A.]

XIV.—*Notice of a second Species of* Paragorgia *discovered in Madeira by* Mr. James Yate Johnson. By Dr. J. E. Gray, F.R.S.

Mr. James Yate Johnson, along with a large and most interesting collection of fish from Madeira, has sent to the British Museum a very fine and large specimen of *Paragorgia*.

The species on which the genus is established is found on the coast of Norway, and is the subject of an elaborate memoir, illustrated by excellent figures, by Kölreuter, in the 'Novi Commentarii Acad. Petrop.' 1758 & 1759, p. 345, tab. 13, 14, 15 & 16.

It was first described and figured by Clusius (Exotic. p. 119), who gives a good figure of the stem, and who received it from Norway.

It is well described by Pontoppidan (Norges Natuurlige Historie, i. No. 12. fig. 5). He figures two varieties, one much more slender than the other.

It is also well described and figured by Esper, Pflanzenthiere, iii. 10, t. 1 *a*, with yellow, and t. 1 & 1 *b*, with redder bark.

All these works describe the polypes as congregated in short, roundish tuberculiform branches on the large, slightly branched main stem.

The specimen from Madeira resembles the Norwegian specimens in many characters, especially in the thickness and compressed form of the main stem; but it differs from that species in being studded with numerous slender, repeatedly-divided branches, which are covered on the upper surface with numerous